ATROP – Autonomous Topology-Optimized Routing Protocol

1. Abstract

ATROP (Autonomous Topology-Optimized Routing Protocol) introduces an AI-native routing protocol that combines an Artificial Intelligence (AI)-driven control plane with Machine Learning (ML) embedded in the data plane. Designed to be vendor-neutral, hierarchical, address-agnostic, and topology-aware, ATROP enables dynamic self-optimization across intra- and inter-domain networks. It provides native support for greenfield and brownfield deployments and full interoperability with legacy protocols such as OSPF, BGP, MPLS, and Segment Routing.

2. Motivation and Problem Statement

Traditional routing protocols operate with rigid state machines, static policy enforcement, and a limited understanding of real-time context. They fail to adapt dynamically to shifting topologies, business intent, and flow-level behaviors. As networks scale across domains (data center, WAN, edge, 5G, IoT), a new model is needed - one that is autonomous, context-aware, and self-optimizing.

3. Protocol Vision and Goals

Vision: To redefine the routing fabric by enabling networks to autonomously learn, optimize, and secure themselves - per topology, per flow, and per intent.
Objectives:
- AI-Based Control Plane for predictive and strategic decision-making.
- ML-Augmented Data Plane for real-time, flow-aware adaptability.
- Hierarchical Topology Zones (ATZ) for scalable, distributed autonomy.
- Protocol Independence with full interop via translation layers.
- Security by Design with cryptographic identity, zero-trust, and anomaly detection.
- Live Deployment on Device OS, not virtualized.
- Vendor Readiness for Cisco, Juniper, Arista, Huawei, and others.

4. Technical Architecture

Dual-Plane Intelligence:
- Control Plane (AI): Uses GNNs and RL to assess topology and enforce intent-aware routing.
- Data Plane (ML): Classifies flows in real time and adjusts forwarding based on observed behavior.
Core Components:
- Node Identity Vector (NIV), Path Intelligence Vector (PIV), Intent Descriptor (IDR), Feedback Injection Field (FIF)
Hierarchical Abstraction:
Node Tier → ATZ (Zone) Tier → Domain Tier → Global Tier

5. Interoperability and Coexistence

ATROP includes adapters and translators for:
- IGPs: OSPF, IS-IS, RIP, EIGRP
- EGPs: BGP/MP-BGP
- Labeling: MPLS, SR-MPLS, SRv6
- Encapsulation: VXLAN, LISP, GRE, IP/IP6
It supports both passive observe, advisory overlay, and active enforcement modes.

6. Security Architecture

- Zero Trust Adjacency Model: Enforced via session validation and dynamic trust scoring.
- Per-Hop Cryptographic Validation: Prevents spoofing and prefix hijacks.
- AI-Driven Threat Detection: Detects loops, blackholes, DoS, and prefix hijack attempts.
- Compliance: Aligns with IETF (RFC 3552, 6811, etc.) and IEEE 802.1X, 802.1AE.

7. Deployment and Integration

Greenfield:
- Full ATZ design
- ML/AI embedded across stack
- Hardware support via programmable ASICs
Brownfield:

- Overlay support
- Legacy protocol redistribution
- Lightweight agents for telemetry and ML feedback

8. Vendor Integration Roadmap

Certified integration profiles are proposed for:
- Cisco (IOS-XR/NX-OS)
- Juniper (JunOS/Paragon)
- Arista (EOS/CloudVision)
- Huawei (VRP/iMaster NCE)
- White-box/Open Source (SONiC, FRR, VyOS)

9. Protocol Standardization Strategy

IETF Alignment: Intended for submission to IETF RTGWG and IDR WG.
RFC Draft-00 target: Q1 2026 (Experimental Track).
IEEE Collaboration: Targeting 802.1/802.3 working groups for MAC/PHY and TSN extensions.
OpenLab and GitHub Contributions: SDKs, testbeds, and telemetry stacks under open-source governance.

10. Commercial and Ecosystem Value

- Vendor Co-Branding Opportunities
- SLA Monetization via Intent-Aware Routing
- AI/ML Add-on SKUs
- Green Routing = Energy Savings
- Standardized Certification Framework (ATROP-CA)

11. Summary

ATROP merges AI-native control with ML-augmented data flow, representing a clean-slate reimagining of routing: dynamic, decentralized, secure, and truly autonomous. With layered abstractions and full protocol interop, it prepares the industry for an era where networks don't just carry traffic - they learn from it, optimize it, and defend it.